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OYSTER CONSERVATION PROBLEMS ON THE POTOMAC RIVER

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The Compact of 1785 between Maryland and Virginia contains two sections which have greatly restricted the regulation and management of the oyster industry of the Potomac River: (1) any licensed oysterman of either state may work in the central portion of the river, and (2) laws regulating the fishery must be acted upon concurrently by both states before they are effective. The fact that the Maryland legislature meets only in odd-numbered years and the Virginia legislature in even-numbered years makes the problem especially difficult. The result is that there has been very little management of the Potomac River oyster resources except for regulating length of season and size of oysters which may be taken. The fishery has been essentially an exploitation of a natural resource with no serious attempt to increase the supply by means of recognized oyster management practices.

No figures are available for the annual catch of oysters in the Potomac River, but the annual production has certainly declined from the 1,600,000 bushels estimated by Stevenson for the late 1800's. During the period 1870-1900 the entire Bay dredging fleet of 400 to 600 boats was reported to work the river each fall.

Not until 1912 were the first concurrent laws enacted regulating the oyster fishery in the river. These included a $2\frac{1}{2}$ inch cull law and establishment of a seed area in the upper part of the river. In 1928 at the request of both states, the U. S. Bureau of Fisheries surveyed the principal bars of the river and found them all greatly depleted. As a result the river was closed to dredging in 1931 and has remained closed ever since. Illegal scraping and dredging, however, have been practiced on both sides of the river in spite of law enforcement attempts. One has only to examine the winter issues of Fishing Gazette and Atlantic Fisherman to learn how open and flagrant this violation has been.

Several good setting years in the early thirties produced some improvement and led to agitation to have the bars reopened to dredging. In 1934 Virginia passed a bill permitting scraping in the Potomac River but Maryland has never concurred, believing that the improvement has not been sufficient to warrant the more efficient type of oystering.

Early in 1942, the Maryland Department of Tidewater Fisheries requested the U. S. Fish and Wildlife Service to resurvey the oyster bars in the river to determine if the amount of improvement since 1928 were sufficient to support dredging. This survey was begun in November 1942 and completed in July 1943.

The Department of Tidewater Fisheries provided a 52 foot boat equipped with power winders and 3 dredges for use on different types of bottom. Each oyster bar was sounded out with a lead line and buoyed off. An approximate topographical survey was then made using a taffrail log and the ship's compass. On a map of the bar constructed from these data, each dredge haul was subsequently located in its proper position drawn to scale. Per acre figures for numbers of marketable oysters, small oysters and spat, and volume of shells for each dredge haul were calculated from the dredging data and located on outlines of the bars in the position of the corresponding dredge hauls. Areas of concentration were immediately apparent, permitting the

drawing of lines separating arbitrary isopopulation areas, somewhat similar to those established by Moore in his numerous surveys.

First of all the survey demonstrated that oysters are not uniformly distributed over a natural rock of appreciable size. For instance, almost a third of all marketable oysters occurred in the two highest isopopulation regions which comprised only 1/10 of the total area of the bars. Likewise almost 2/3 of all small oysters were found on 1/7 of the total area, and 96% of the small oysters were concentrated on less than half of the total area of the bars.

In the second place the survey demonstrated that the numbers of oysters on the bars are still small compared with potential and desired productivity. The entire 3300 acres surveyed averaged only 10 bushels of marketable oysters per acre and 2200 small oysters per acre. Half of the area contained only 4 bushels marketable oysters and fewer than 300 small oysters per acre. Greater concentrations of oysters were found, but the total acreage of these was small. For example, only 76 acres (2.3% of the total area) contained more than 30 bushels of marketable oysters per acre and 178 acres (5.2% of the total) contained more than 10,000 small oysters per acre.

These figures are somewhat smaller than the actual numbers of oysters on the bars because of the inability of the dredge to catch everything in its path, as demonstrated by counts made directly on the bottom with a diving helmet. Unfortunately, the efficiency of the dredge varied so greatly with character of bottom and size and type of oysters that no correction factor could be derived applicable to all the dredge hauls.

However, since both the 1928 and 1942-43 surveys were made with the same type of equipment, the results are comparable. During the period between these surveys large oysters exhibited a 10-fold increase and small oysters approximately a 20-fold increase, but as previously stated the present populations except for limited areas are still very small.

Various factors have affected the annual production and helped keep it at a low level. For all 3 years in which records are available--1928, 1942, 1943-- intensity of setting on natural cultch has been greatest near the mouth of the river, decreasing gradually towards the upper limit of the oyster area. Apparently, the lower half of the oyster region receives a set almost every year, with the result that the oysters tend to be clustered. The upper portion of the river receives a set only occasionally, as in 1941; here the oysters usually are separated and well formed. Natural cultch is most abundant in the upper part of the river where setting is usually lightest.

Sixty percent of the 1943 spat were attached to old oysters, most of which were of marketable size. Because of the difficulty of freeing spat from larger oysters, it is unlikely that more than a small percentage of the spat removed from the water during the past oyster season were returned to the bars. Hence, under the present management of the river, a large proportion of each year's set is taken from the water before it can contribute to commercial production.

Spring freshets and floods may affect the annual production of oysters in the river by influencing spawning and setting, but perhaps the main effect is to cause occasional mortality on the uppermost bars. The flood of 1936 is reported to have killed many oysters in the river as far downstream as Cobb Island Bar. It seems likely from the meager information available that the upper limit of sustained oys-

ter growth approximately coincides with the average downstream extent of spring fresh water in the river.

Other organisms can influence annual production. The oysters on Wakefield and Old Farms Bars on the Virginia side of the river were so thickly overgrown with bend-nose mussels that they had little market value this past season.

In summary, the present system of management of the bars is inadequate to increase and maintain production above a somewhat unstable low level, determined by various environmental factors and the rate of fishing. The period from 1931 through 1943, during which harvesting had been curtailed to tonging and illegal scraping, has demonstrated that the oyster bars by themselves cannot regain their former productivity.

Certain areas in the lower part of the river where setting is adequate require more cultch and separation of the clusters of oysters. Extensive areas on the bars in the upper part of the river could be profitably planted with small oysters, and some areas on these bars should have shells planted to help reinforce the bottom.

Improvements of this type require the expenditure of money, but past experience has demonstrated that Maryland and Virginia cannot agree upon a division of such expenses. It would perhaps be simplest for the bars on either side of the river to be under the complete control of the adjacent state, but this could not be accomplished without a revision of the Compact of 1785. It has been recommended, therefore, that a bi-state commission of representatives from both Maryland and Virginia be established with the power to regulate and manage the Potomac River oyster bars according to recognized principles of oyster culture and management. Continued study of the oyster biology is necessary to formulate management policies for the individual bars.

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ALABAMA PROGRAM OF REHABILITATION

By James B. Engle
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The fine oysters produced on the natural reefs of Alabama leave nothing to be desired but more of the same product. A recent survey of the reefs suggested a need for a program to increase production to an amount adequate to supply the oyster demands of Alabama, as well as the market furnished by nearby states for the same oyster. The reefs of Alabama have sufficient area and potential productivity to support a stepped up program part of which would be rehabilitation, and another part, of much more importance than the first, of cultivation.

At present there is a low yield of oysters from all but a few reefs. The reefs that are maintaining a good supply of oysters both large and small are located mainly in the pass between Mobile Bay and Mississippi Sound. The large reef called White House, north of the pass and in Mobile Bay proper and another called Sand Reef also in the Bay, but south of the pass are two other sources of good yielding reefs. White House reef, however, is subject to freshet damage when the two large rivers that feed into the northern part of Mobile Bay reach excessive flood stages. Most of the above reefs grow oysters in thick clusters. The density of the growth is in itself an inhibiting factor in the process of producing quality oysters. On the other hand, this same oyster if transplanted or thinned out will improve in shape and market value by a margin that would more than compensate for the additional work involved.

The seafoods section of Alabama Department of Conservation has recognized this and has provided for the removal of unculled oysters for transplanting during a portion of the winter and early spring. This, of course, is to encourage private enterprise, and its indirect effect would be to thin out the overcrowded conditions. There is ample bottom within riparian jurisdiction for private interests to make use of part of this seed supply. The State, which controls all the bottom outside the riparian ownership, also provides for leasing of suitable areas for the development of private planting grounds in the public domain. From the evidence supplied by the State report for 1942-43 the area leased was sixty-four acres. In time and with enough encouragement more individuals will realize the advantages in oyster farming over wild fishing and participate in the cultivation of oysters.

Of equal importance is a part of this same seed supply that could be used by the State to rehabilitate the low yield reefs situated in other parts of the Alabama public oyster growing region. In the past such a program has been promoted but not in a sustained way that would stabilize the supply.

With the seed supply available it is now possible to look at another side of the Alabama oyster picture that showed up with startling clearness during the survey just completed. The reefs of the eastern portion of Mobile Bay also known as Bon Secours Bay were producing oysters in very limited numbers in proportion to the size of the area. The figures showing the actual population of the eastern reefs appear in the official report of the survey. It is sufficient here to say that the residue after the 1943-44 crop is removed will practically deplete the reefs. Furthermore, the number of replacement spat and oysters is also very small and entirely inadequate

to supply the quantity of oysters [illegible] equal what was taken off the Eastern Bay reefs. The oystermen fishing th[illegible] Secours Bay reefs did manage to tong oysters in quantities enough to get a financial return sufficient to equal a day's pay even during these times, only because of the high, abnormally high, prices paid for their oysters. Next year will be different unless some steps are taken to replenish the marketable oyster population now gone, but by no means forgotten.

The above statement, while in part pessimistic, is made only as an opening for a suggested plan of State management and maintenance that should prove in my opinion advantageous to the parties involved from the State to the consumer. The State at present is doing a fine job of protecting, and within the means at its disposal, increasing the public oyster heritage. All the shells of the present shucking season (1943-44) now belong to the State who plans to return them to the public beds and bottoms. Many of these shells are already replanted and at the present time, we hope, are catching spat so much needed. The beneficial results of this operation will be felt in subsequent years, for shell planting has proven its value in all oyster growing regions, (a statement hardly necessary here however) and should also bring the same results to Alabama.

Shell planting is insurance for the future but the need in Alabama is present. The depleted Bon Secours reefs need a transfusion which could be best accomplished by a seed planting program. The Bon Secours Bay area has no reef or reefs with enough young oysters to furnish the replanting stock, but there is ample seed on many of the reefs on the western side of Mobile Bay which actually needs removal for the good of the overstocked reef. With the State having full jurisdiction over the reefs, the task of replanting the seed becomes one of labor and timing. The earlier the work is done the less chance there is of seed mortality because of the heat.

On the basis of my recent survey I feel that eventually the Bon Secours reefs could be restored by shelling and the judicious use of spawners. The urgency of the situation, however, requires other treatment which might be called a compromise. The larger reefs should be divided and one portion shelled. Shelling, however, must be well timed to prevent fouling. A mud and fouling organism coating covers most of the shells and oysters on these reefs. It appeared from the few of 1943 oyster spat that were present, that the set occurred early in the summer during late May and June. The time could best be established by an oyster culturist on the beds and his calculations could make more certain a successful set by assuring the coordination of the shell planting with the approaching maturity of the swimming oyster larvae. I am convinced that a replacement supply of seed or setting oysters can be caught on the Bon Secours Reefs.

The other portion of the reef can be seeded with unculled oysters from the western reefs and these oysters brought in will form the spawners needed. The thickness to plant the seed will depend on the supply but it is safe to put up to 150 barrels per acre on the reefs. The planting will be much less than the good oyster bottom can stand but ample to make oystering profitable during the next two years.

The above suggestion, of course, is an initial operation in a program to make the reefs self-sustaining. After the seeded areas have been marketed within one and two years that area should be reshelled and the originally shelled area after two years would be ready to yield some market stock. The State would probably have to stagger the use of some of the reefs to permit an extra year's growth to accumulate. The Alabama oyster on some reefs reaches market size in less than eighteen months so it is perfectly feasible to expect some marketable return in two years from the planted shells. In my opinion, however, one more year of growth would make a more

desirable oyster and help to maintain the usual high quality of Bon Secours oysters.

Culling some of the small oysters from the shells of the larger ones is often impossible, but at the same time the loss of these small oysters when they die on the shell piles may be a factor in the eventual depletion of a reef. In 1936 when I had the privilege of inspecting the reefs and the methods of oystering in these waters that loss appeared to me to be remediable. It was suggested then that an effort be made to get these shells containing live small oysters back on nearby suitable bottom. I was gratified to see during this recent survey that this practice was in operation. The shucking house with a bed near the house might well profit by saving the young oysters reaching it this way. At present the State is managing this operation.

Rebuilding beds is important but costly. Maintenance once the reefs have been put in this condition would be cheaper and produce a more sustained production through the plan outlined above. The oyster grown on the Bon Secours reefs is a fine shaped, fine flavored oyster, and if it is able to be raised there from the set collected on the planted shell it would be a source of satisfaction to many oystermen who make their living there. It would eliminate also a vast amount of sectional friction aroused when western oysters are transplanted to eastern beds.

One more thing I must mention in the interest of the conservation of oysters in Mobile Bay, and that is to utilize to the fullest the oysters from White House Reef. The oyster here grows quickly and thickly but periodically flood waters from the upper Mobile Bay, which is fed by the Alabama and the Tombigbee Rivers, destroy large numbers of them. The reef rehabilitates itself quite readily after freshet damage. If these oysters are removed shortly after they set and planted on safer reefs it would conserve many oysters that have been lost in the past.

In closing it is appropriate to say that Alabama has the potential facility to increase its production many fold through a planned program of State managed oyster cultivation. Some phases of it are under way right now, and the most recent report indicated an upward trend in production. In the course of time as funds and experience accumulate, Alabama will be able to eat all of its own oysters it desires, and offer to other markets its surplus.

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PROBLEMS OF REHABILITATION OF CHESAPEAKE BAY OYSTER RESOURCES

By Paul S. Galtsoff
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The story of the oyster fishery of the Chesapeake Bay is a sad example of the rise and decline of a valuable sea food industry which used to provide comfortable livelihood to thousands of citizens, spread the fame of Maryland and Virginia oysters to the remotest corners of the world by supplying the well known canned "Cove Oyster" and experienced a precipitous downfall. For instance, today not a single oyster canning house is found in the City of Baltimore in which nearly three scores of establishments produced canned oysters in 1890. Statistical data show that between 1880 and 1936-37 the total value of the oyster product, handled in this city alone, declined from $3,900,000 (in round figures) to about $1,500,000.

This decline common for the entire upper part of the Bay has not been caused by natural changes in quality of the water or of the bottoms, the potential productivity of which remains today the same as it used to be in the past. So far the inroads of domestic and industrial pollution in Maryland waters have been limited to the relatively small areas near larger cities and have not seriously affected the principal oyster bottoms. An entirely different picture is found in Virginia waters where thousands of acres of excellent oyster grounds were rendered unsuitable for the production of oysters for market because of the increased domestic and industrial pollution. The upper part of the Bay has further advantage in being free of drills which annually destroy millions of oysters in the lower part.

The decline in the productivity of shellfish bearing bottoms of the Bay has been the result of a disregard of the fundamental principles of conservation. For more than a hundred years the oyster bars and reefs of the Chesapeake Bay were subject to fishing without consideration to the rate of natural replenishment and more oysters were taken annually than could be reproduced by propagation and growth. No wonder that many productive grounds became so depleted that their annual productivity of about 40 bushels per acre declined to only a few bushels. The depletion of some of the grounds was so great that their self rehabilitation became impossible without replanting. No further proof is required, however, for a statement that through the application of oyster farming the productivity of oyster bottoms can be maintained on a sustained yield basis or even materially increased. Suffice to mention that private oyster farming in New England and in the State of Washington was very successful not only in maintaining high production levels but also in converting many thousands of acres of non-productive bottoms into fertile farms under water.

When the country is in need of protein food, the question who would produce it has but little significance. It is, therefore, immaterial from a national point of view whether oyster bottoms are cultivated by private planters or by the state governments which have jurisdiction over the inshore fisheries. It is important, however, that the existing oyster bars or reefs be efficiently utilized to permit maximum harvesting without depleting the resource. This requires introduction of an effective system of exploitation and management.

Since the public opinion in the Chesapeake Bay States and specifically in Maryland is opposed to private planting, the state governments have no other alternative but to enact a system of exploitation of public grounds which would maintain their productivity on a sustained yield basis. It is one of the purposes of the investiga-

tion conducted by the Fish and Wildlife Service in the Chesapeake Bay to provide factual data necessary for the management of state oyster resources.

Lack of seed oysters is at present the greatest handicap in the development of the oyster industry. It is a well known fact that certain areas are more adaptable to the production of seed oysters than to growing oysters for the market. It is our intention to locate these areas and to find out how by better timing of planting or by using collectors to produce more seed per unit area than can be obtained without the aide of these methods.

Good oysters, like good vegetables and other crops, require good care. They should be properly thinned to avoid overcrowding or they may be transplanted to special bottoms for rapid growth and fattening. The growing bottoms should be located and the conditions under which oysters would ripen and fatten should be recorded and analyzed. In the past many failures in the cultivation of oysters were due to overcrowding; i.e., planting more oysters than the bottom was capable of supporting. Whether any given bottom is good to grow 500, 1000, or even 1500 bushels of market oysters per acre must be studied and determined by experiment and observation.

It is expected that some of the questions will be answered in a short time while others will require time-consuming and intensive studies before the solution can be found. Thanks to the excellent cooperation offered by the State Commission of Tidewater Fisheries, the Maryland Department of Research and Education, the Virginia Fisheries Commission and a number of private oyster growers, the work will be carried out on a large and comprehensive scale commensurate with the importance of the project. The Service hasalready established field headquarters at Annapolis, Maryland, for the upper part of the Bay and at Cambridge for the work to be conducted along the Eastern Shore, Tangier Sound and adjacent areas. Observations on time of spawning and setting of oysters and their growth on various grounds are being conducted at several places in these two areas.

Already interesting observations have been made in the upper part of the Bay where the raise of stage of the Susquehanna River has reduced the salinity at Lee Table and other bars to almost fresh water. Careful check is being made on the survival of these oysters and the ripening of their gonad. It is expected that this summer observations will provide reliable information regarding the role of this section of the Bay as a natural breeding area.

The oyster studies in the lower part of the Bay consist primarily in determining the degree and the trend of the domestic sewage pollution with special reference to marginal areas which, it is hoped, may be saved to oyster growers if disposal and purification plants are constructed in the Hampton Roads metropolitan area. The losses sustained by the oyster industry of this section because of the pollution of water are very great. The U. S. Public Health Service estimated that in 1934 the loss due to pollution amounted approximately to $570,000 annually. In present years the situation was greatly aggravated by a great influx of population and corresponding increase in the pollution of water. One of the aims of the investigations conducted by the Service at Hampton, Virginia, is to learn more about the relationship between the various bacteria in the sea and the oysters and on the basis of these studies to develop a practical method of purification of shellfish. It is believed that some of the bacteria may be of great benefit to the oysters because they may contribute to the diet of the oyster larvae or adult, or help in converting into food materials the various substances which normally occur in the sea. Very little is known regarding these problems which will be studied from our headquarters at Hampton. It is hoped that these investigations will provide the data needed for the

protection and improvement of the shellfish bearing bottoms of the state and will lead to better utilization of the valuable shellfish resources and their eventual rehabilitation.

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FEEDING AND FATTENING OF OYSTERS

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The oyster industry of New England, as well as any other section of the United States, is faced with three basic problems, the solution of which should guarantee an abundant supply of good, marketable oysters. The problems are as follows:

1 - to obtain regular and sufficiently heavy oyster sets to perpetuate the industry.

2 - to protect the set and young oysters against their enemies, chiefly starfish and drills.

3 - to condition adult oysters for the market.

In recent years, the first two of these problems have received considerable attention, and definite progress has been made in these fields. The third problem, however, was studied less extensively and, as a result, we know comparatively little of the conditions which are important in the fattening of oysters.

It cannot be overemphasized that the condition of the oyster meats spells either success or failure for the oystermen. This is especially true for the men engaged in the cultivation and shucking of oysters of marketable size. An extra pint of meats per bushel of oysters often represents the narrow margin that means a profitable year.

In nature, the years of fat oysters are often succeeded by periods when the oyster meats are extremely poor. These periods represent a very serious handicap to the industry and, usually, result in financial losses. Naturally, the answer to the question as to what conditions cause the oysters to become fat is of equal interest to practical oystermen and to scientists engaged in the study of oysters.

In an attempt to contribute to the solution of this problem, the authors undertook a study of the food, feeding and fattening of oysters. Although this work, which began several years ago, is still in progress, some of the information already obtained may be of interest to the men engaged in the oyster industry. Short preliminary reports of our studies have already been published in Vol. 84 of ANATOMICAL RECORD, 1942, and in Vol. 4, No. 1 of SOUTHERN FISHERMAN.

The chief difficulty encountered at the beginning of our studies was the lack of a method which could enable the investigators to grow large quantities of plankton forms, considered as constituting part of the oyster diet. In a conference held at Milford Laboratory in 1940 by members of the Division of Shellfisheries Investigations, the necessity for devising such methods was strongly stressed. Somewhat later, the authors were fortunate enough to develop a method by means of which a large quantity of various organisms could be easily grown. This simple method was described in an article published in SCIENCE, Volume 95, No. 2471, 1942. It proved to be extremely efficient, and, as a result, we were able to grow thousands of gallons of rich plankton cultures for our work.

After the development of this method, it seemed that the solution of the problem was near at hand. It was thought that by employing the method, the number of food organisms could be quickly increased to such an extent that a superabundance of plankton would exist in the water over the oyster beds. Therefore, the oysters would have enough, or more than enough, food and should fatten quickly. Unfortunately, further experiments showed that the problem was of a more complex nature than it appeared at first.

In our early experiments, conducted at Milford Laboratory, the oysters were kept under such conditions that the food organisms were always present in very large numbers. Regardless of the abundant food, however, the oysters failed to develop fat meats. As a matter of fact, they became progressively poorer, and if kept in water containing an extremely heavy concentration of food forms, very often died. Strange as it seemed at that time, the animals fed smaller quantities of food showed less pronounced ill effects, whereas the oysters fed only a limited quantity of food did very well, and became fatter.

The results of the experiments at first appeared to be a paradox. They showed that the oysters in the midst of plenty were probably starving, while those given only limited quantities of food became fatter. This conclusion contradicted the established conceptions on the feeding and fattening of oysters and, naturally, an explanation was needed to clarify the confusing results. Such an explanation could be provided only by an extensive series of experiments designed to study the feeding activities of oysters when exposed to different concentrations of microorganisms. A brief description of some of the experiments is given below:

The animal used in our work was the common American oyster, _O_. _virginica_, of Long Island Sound. The age of the experimental animals varied from 4 to 6 years. The microorganisms, the effects of which were studied, were (a) a green alga - _Chlorella_ sp.; (b) a diatom - _Nitzschia closterium_; (c) a dinoflagellate - _Prorocentrum triangulatum_; and (d) a euglenoid - _Euglena viridis_. Thus, the selection of forms used included a representative species of 4 very common groups of organisms which are considered as constituting a large percentage of oyster food. The size of the forms varied from 5 microms, in the case of _Chlorella_, to 60 microms in the case of _E_. _viridis_. Such a selection of size was governed by the consideration that the size of the food organisms may have certain effects upon the feeding behavior of the oysters. These forms were identified by Dr. James B. Lackey of the U. S. Public Health Service, to whom the authors wish to express their thanks.

Because of the limited time allowed for this report, we shall not discuss in detail the effects of all the 4 forms mentioned above, but will confine ourselves largely to a discussion of the experiments in which _Chlorella_ was used. It should be emphasized, however, that, in general, a very great similarity existed in the results obtained with the different forms.

In the first rather exploratory series of experiments the oysters were exposed to a constant flow of _Chlorella_ cultures of different concentrations. Prior to that, however, the oysters were kept in sea water for several hours to obtain a record of their activities under normal conditions. In all heavy concentrations of _Chlorella_, the flow of water filtered through the gills of the oysters markedly decreased. As compared with the quantity of water pumped by the same oysters prior to exposing them to _Chlorella_, this decrease varied from 69 to 90 percent in very heavy concentrations, while in somewhat lighter ones it ranged from 19 to 56 percent.

Studies of the shell movements showed that exposing the oysters to heavy con-

centrations of microorganisms did not materially decrease the time the oysters kept their shells open. It revealed, nevertheless, that the type of shell movement was different from that observed while the animals were kept in running sea water.

In light concentrations of Chlorella, as well as in the other microorganisms, the rate of water flow was not reduced. In some instances it was even greater than during the preceding period, when the oysters were kept in running sea water. The character of the shell movements of the oysters and the time the shells remained open showed no significant change.

In view of the results obtained, it was thought desirable to determine more accurately the minimum concentrations of microorganisms unfavorably affecting the oysters. Therefore, a series of experiments was designed in which the animals were subjected to gradually increasing concentrations. In very light concentrations no appreciable change was noted. However, upon introducing medium heavy cultures, the rate of water flow produced by the oysters sharply declined. A subsequent increase in the density of the cultures resulted in a further decrease in the rate of water flow. In general, the decrease in the rate of pumping became more pronounced as the concentration of microorganisms became heavier. In the heaviest concentration many individuals ceased pumping entirely, while in others the rate of flow was only from 8 to 21% of that recorded in sea water before the oysters were subjected to the experimental conditions.

When, at the end of exposure, the oysters were again subjected to sea water, the rate of flow showed a marked increase. In many cases it was much greater than the original one. Such intensive pumping suggested an attempt by the oysters to cleanse themselves from the microorganisms which accumulated in the mantle cavity and gills.

The oysters exposed to increasing concentrations of microorganisms did not show a radical change in the percentage of time their shells remained open. Observations on the shell movements, however, revealed two facts of considerable significance. First, it was noted that in several instances the shells of the oysters remained open for long periods, sometimes lasting several hours, while the animals did not pump any water. This observation showed rather conclusively that although the shells of the oysters are open, this fact does not always mean that the mollusks are feeding.

The second observation indicated that upon the introduction of large numbers of microorganisms in the water surrounding the oysters, the shell movements of those animals became abnormal. They showed that the oysters were struggling against unfavorable conditions, ejecting large quantities of pseudo-faeces at very frequent intervals. The kymograph records of the shell movements closely resembled those obtained in the experiments now being conducted at Milford Laboratory in which the oysters are subjected to a heavy concentration of silt suspended in the water.

In the next series of experiments the process of exposing oysters to different concentrations of microorganisms was reversed. The animals, after having been kept in sea water for several hours to observe their normal behavior, were subjected to decreasing concentrations of plankton. The first concentration, used immediately after the initial exposure of the oysters to sea water, was extremely dense. Contact with such a thick population of microorganisms always resulted in a rapid and marked decrease in the rate of pumping. In some instances it caused the complete cessation of pumping, as if the oysters were unable to cope with the mass of cells present in the surrounding medium.

As the experiment progressed and the number of microorganisms became smaller, the oysters pumped more water. In general, the increase in the rate of pumping was rather parallel with the decrease in the number of microorganisms.

The results of all these experiments could be briefly summarized as follows: the rate of water flow produced by the oysters usually decreased with the increase in the number of microorganisms present in the surrounding water. The size of the cells plays an important part in affecting the rate of pumping. A much greater number of small-sized cells, such as Chlorella, was necessary to produce the same effect as that caused by a small number of larger organisms, such as Euglena.

As a result of the above mentioned, and many other, observations of a similar nature, it has become evident that the oysters are at a disadvantage when the surrounding water contains a large number of microorganisms. Additional experiments conducted in large outdoor tanks and aquaria, where the oysters were in contact with different quantities of food cells, fully supported this point. We were able to fatten the oysters by giving them relatively small quantities of food, but also were able to render them very poor, and sometimes cause their death, by adding a large quantity of microorganisms to the water.

Upon arriving at the above conclusions we communicated with Mr. Joseph Glancy, who is working with oysters in Great South Bay, and discussed our results. It was the opinion of all of us that the poor condition of the oysters of Great South Bay was due to the presence of large numbers of small plankton forms. Analysis of the samples of water sent to us by Mr. Glancy showed that the density of microorganisms in Great South Bay was greater than that which, according to our experiments, was safe for the healthy existence of oysters.

By using our plankton culture methods, we succeeded in cultivating the forms present in the water of Great South Bay, and subjected some of the oysters to various concentrations of those microorganisms. We found that in strong concentrations the animals became extremely poor. In several instances the individuals developed black gills, a phenomenon so well known in Great South Bay. In other cases we took the poor, black-gilled oysters and placed them in water containing but few food organisms. The animals rapidly recovered and became fatter, although the gills remained black for quite some time.

The question which naturally arises is why the water of Great South Bay is so rich in plankton. Undoubtedly, the answer should be sought somewhere along the factors which are responsible for a rich plankton growth. In the laboratory we obtained rich cultures by adding fertilizer to sea water. Is it possible that in the case of Great South Bay the abundance of small aquatic forms is also caused by an excess of some fertilizing substances? When discussing this problem at one of our meetings, the suggestion was made that the rich growth of plankton in the Bay is due to the large quantity of organic matter washed in from the surrounding areas, where numerous duck farms are located. Certain facts indicate that such a suggestion may be based upon a sound foundation. Thus, it is possible that we are facing a problem of over-fertilization of a body of water.

An explanation is, of course, needed to show why in the presence of a large quantity of food the oysters become poor, and even die. The answer is based upon the observation that when large numbers of microorganisms are present in the water they seriously interfere with the normal functions of the oyster gills. In filtering the water rich in plankton the oyster gills, which are very delicate and sensitive organs, become quickly clogged with the mass of food cells. This condition in-

terferes with the normal feeding of the oysters and, to a certain degree, with their respiration. The records of shell movements obtained in our experiments, as well as direct observations upon the oysters, showed that when microorganisms are abundant the animals are largely preoccupied in keeping their gills clean. This is manifested by the characteristic movements of the shells to expel large quantities of pseudo-faeces. At the same time no true faeces are being formed, this fact indicating that the oysters do not feed.

Examination of the stomachs of the animals kept in heavy concentrations of microorganisms showed the absence of food and crystalline style. Obviously, regardless of the abundance of food in the surrounding water, the oysters were starving.

It should be made clear that these results were obtained in the experiment in which the oysters were kept in large quantities of water. This measure was found necessary to avoid the erroneous results and conclusions that might have been formed if the oysters were confined to several quarts or even gallons of the liquid. In such cases, the mollusks by forming large quantities of pseudo-faeces, might quickly reduce the concentrations of the cells below the danger level, and then proceed to feed in a normal way. This would be impossible if the oysters were surrounded by large quantities of water rich in microorganisms.

In our studies it has been found that the Chlorella cells, if filtered off from their medium and then added to the sea water in which the oysters are kept, will reduce the rate of pumping of the animals. This perhaps could be interpreted as a mechanical interference with the pumping mechanism of the oyster. Such a conclusion is supported by the experiments now being carried on by Dr. Loosanoff and his assistants at Milford Laboratory, in which, instead of plankton forms, various inert substances, such as bottom silt, kaolin, precipitated chalk, etc., are added to the water to increase its turbidity. The results of the experiments also showed that the particles suspended in the water cause a reduction in the quantity of water pumped by the oysters.

In still another experiment it was found that clear Chlorella filtrate from which all the cells are removed, would also reduce the rate of pumping, and noticeably change the character of the shell movement of the oysters. Apparently, in this case, the action is chemical. Perhaps Chlorella cells, while in suspension, produce certain inhibiting substances which adversely affect the oysters. Experiments are being conducted to determine the exact nature of this substance, if it exists. Possibility of its existence is rather likely because of the observations of many other investigators on the mortality of shellfish and fish caused by the abundant growth of plankton. Incidentally, a recent interesting work by Pratt has shown that Chlorella cells form a very powerful growth-inhibiting substance which limits the growth of its own population.

Our laboratory experiments were to a large extent corroborated by observations of the conditions existing in nature. For example, as is well known, the oysters of Great South Bay have been poor for a period of several years. Examination of these animals showed they were emaciated to such an extent that their meats were almost transparent. During the same period the water of the Bay was extremely rich in organisms, which are thought to be used as food by oysters. Thus, the presence of a large quantity of food did not render the oysters fat. Mr. Glancy, with whom we had a number of discussions regarding our experiments, and who has observed conditions in Great South Bay for the past 20 years, has informed us that the animals usually become poor when microorganisms are present in large numbers. Perhaps there are some other undiscovered factors which contribute to the poor condition of the oysters of

that body of water but the fact remains that the animals are in such a state regardless of the abundant food supply.

As an example of the opposite case, we may mention Gardiners Bay, Robin Island Sound, Shelter Island Sound and other locations of a more or less similar nature. Our own observations, as well as information obtained from practical oystermen, showed that the water in the areas mentioned above is very clear, apparently containing but a small number of microorganisms. Yet, as every oysterman of New England knows, these areas are famous as the grounds used principally for fattening oysters. Thus, in spite of the presence of comparatively small quantities of food, the oysters of these areas become fatter than those living in water much richer in plankton.

In connection with this discussion it is of interest to mention that recent plankton studies in Long Island Sound, carried on by Dr. Riley (1941), showed that plankton was least abundant during October, November and the early part of December or, in other words, during the period when the fattening of oysters takes place in nature. This fact appears to be of considerable significance, perhaps indicating nature's provision to create more favorable conditions for the oysters during their fattening season.

In general, the results of our studies could be summarized as follows; in heavy concentrations of microorganisms the shell movements of the oysters become abnormal showing repeated attempts to expel the mass of food cells accumulating in the gill cavity. The shells may remain open for very long periods although no water is pumped by the animals.

Medium concentrations cause a decrease in the quantity of water pumped by the oysters. Pumping entirely stops in very heavy concentrations. There appears to be a correlation between the number of microorganisms in sea water and the rate of pumping.

In heavy concentrations little or no food is ingested by the oysters and the crystalline style is usually absent. The animals are preoccupied with the formation of large quantities of pseudo-faeces in an attempt to cleanse their gills of the excessive accumulation of microorganisms.

There are more or less definite concentrations of food forms above which the number of microorganisms begins to interfere with the feeding of oysters. The animals kept in water too rich in plankton fail to fatten, whereas by subjecting them to the optimum concentration, which was usually light, a very noticeable improvement of their condition is achieved.

The results of these experiments place an entirely different aspect on the problems of the feeding and fattening of oysters. It appears that in selecting the grounds for the fattening of these mollusks we probably should avoid the areas where the water contains a large number of plankton forms. We may also need to reconsider our previous conception that the addition of fertilizing substances to sea water to increase plankton production is a measure that will eventually result in the fattening of oysters. It is even possible that in order to grow fat oysters, we may need to devise methods for decreasing the quantities of plankton over the oyster beds. The last suggestion is not as far-fetched as it may seem because Miyake reports that the chemical methods of treatment of sea water were employed in Gokasho Bay, Japan, to protect the pearl oysters of that body of water from being killed by an excessive growth of microorganisms.

However, before forming final conclusions more research on the subjects discussed in our paper is necessary. Thus far, our studies have been confined to oysters of the same general locality, living under approximately the same conditions. Therefore, we do not know whether or not the conclusions expressed above would apply to oysters of other geographic areas, where environmental conditions are radically different from those of the New England beds. For example, it is reported that in some places in the south fat oysters are found growing in very turbid water, and in water containing an extremely rich plankton population. Another example is provided in the case of the "claires" at Marennes and other places along the French coast where the oysters, although of different species than ours, are fattened in the presence of abundant supplies of diatoms, peridinians, algal spores and other microscopic vegetable matter. Obviously, further extensive studies are needed before final conclusions may be safely and correctly formed, and the principles developed applied in practice by oyster growers.

National Shellfisheries Association
Atlantic City, New Jersey, Meeting, June 1944

SOME OBSERVATIONS ON THE FOOD AND FEEDING OF OYSTERS IN CHESAPEAKE BAY

By Dorothy Clum Morse

The problem of oyster food and feeding habits has been studied by many investigators during the past fifty years in an effort to aid the oyster industry by finding a clue to the cause of fattening of oysters. Aside from its economic value, the problem is of scientific interest, not only to the oyster biologist, but also to those specialists who study plankton, the small plants and animals found drifting in the sea, and which oysters collect so efficiently.

With the purpose of serving both the oyster industry and science, a program was resumed last fall at the Chesapeake Biological Laboratory in an effort to learn more about oyster feeding habits, which have not previously been studied extensively in the Chesapeake Bay area.

Starting in September, 1943, oysters have been collected from the local bars of the Patuxent River, where the salinity averages 14 parts per thousand, as compared with 35 parts per thousand in the ocean. Samples have been taken biweekly during periods of oyster activity, and less frequently during winter hibernation. Immediately after dredging, the oysters are opened and the stomach contents are removed by inserting a small pipette in the mouth of an oyster on the "half-shell." Samples from about ten oysters are put in a vial and preserved immediately with formalin. The condition of the oyster is noted as very poor, poor, fair, fat or very fat. At the same time, hydrographic data such as surface and bottom salinity, surface and bottom temperature, wind, weather and tide are recorded. Whenever possible plankton samples are collected at the same time by towing a number 20 plankton net over the oyster bed or by obtaining a water sample which is later centrifuged.

To supplement these studies in the Patuxent River, samples of oysters have been obtained whenever possible from various bars in Maryland waters of the Chesapeake Bay. Most of these have been secured under conditions which, unfortunately, prevent obtaining a plankton sample at the same time.

In the laboratory, the stomach contents are carefully studied under the microscope and the dominant organisms are listed. An estimate of the percentage composition of the food is made by counting 200 organisms and dividing by two. Organisms consistently found are diatoms and other algae, Dinoflagellates, Tintinnids, Silico-flagellates, Ostracods, eggs and larvae of marine animals, pollen from land plants, as well as broken pieces of plants and animals, sponge spicules and sand grains. On one occasion oyster meats were a dark red due to the pigment of the Dinoflagellate, *Exuviella apora*, which was found in great numbers in the stomach.

From samples collected to date, it is evident that the feeding habits fall into three distinct periods which coincide with the seasons. These different periods apparently are the result of fluctuations in water temperature and changes in the plankton population.

Last autumn the dominant form found in stomach samples was the small diatom, *Cyclotella striata*, which often made up more than 80% of the food. This species with other diatoms and Dinoflagellates was eaten generally by oysters throughout the Bay area up to the onset of cold weather. It seems to be a favorable diet since the oysters improved constantly and reached their maximum condition of fatness about

the middle of November.

With the approach of cold weather there was a steady decline in the amount of food ingested, until the oysters entered a period of hibernation by the middle of December. The last sample which showed any signs of feeding was collected on December 14, when the surface water temperature was 6°C. (43°F.). Following this, there was a sudden decline in the water temperature, which fell below 5°C. (41°F.), and oysters taken on December 22 had empty stomachs. Inactivity continued throughout the winter until there was a rise in the water temperature in March.

The first sample which indicated resumption of feeding was taken on March 17, when the water temperature on the bottom was 5.2°C. since oysters showed no signs of feeding below this temperature, but resumed feeding when the water temperature rose above 5°C. This agrees closely with the findings of other investigators who have recorded 4°, 5°, and 7°C. as critical temperatures for feeding and muscular movement.

With the resumption of feeding activity, the oysters partake of different food than in the fall, because of the different composition of the plankton. In the early spring, diatoms constitute the bulk of the food, with <u>Cerataulina Bergonii</u> and <u>Nitzschia seriata</u> forming as much as 90%. By the middle of April and later the composition of the stomach samples changes. At this time, at least 50% of the organisms ingested are <u>Cyclotella striata</u>, the same diatom that contributed most to the food in the fall.

When oysters resume feeding, it is not a sudden change, but a gradual transition. As the temperature rises, more and more food organisms are found in the stomachs, and simulatneously the oysters are improving. Below 10-12°C. very few organisms were found in the stomachs, though feeding was in process since crystalline styles were found in some of the oysters. At these low temperatures the oysters were poor. However, when the bottom temperature increased toward 20°C., the oysters showed evidence of eating more and their condition improved, till they were fat and full of diatoms when the bottom temperature rose above 20°C.

By comparing the food of the Patuxent River oysters with plankton collected over the bars, we get further indications concerning the feeding habits. The nature of the food taken by the oyster is, of necessity, determined by the composition of the plankton; however, the same organisms are not always found in samples from these two sources. For one reason, the oysters do not ingest the large spiny diatoms, such as <u>Rhizosolenia</u> and large species of <u>Chaetoceras</u>, the larger Dinoflagellates such as <u>Ceratium</u>, or copepods. These organisms are seldom found intact in the oyster stomach, regardless of their abundance in the plankton. However, it is not uncommon to find that oysters have taken parts of these large organisms, such as copepod appendages and parts of the shell of a <u>Rhizosolenia</u> or a <u>Ceratium</u>. Apparently the size and awkward shape of these forms make them unsuitable as oyster food.

There is still another way in which the oyster food differs from the net plankton. Oysters are able to collect nannoplankton, small organisms which ordinarily escape through the meshes of a plankton net. This source of food is important during some seasons, as last fall and this spring when oysters ate mostly <u>Cyclotella</u>, many of which are too small to be retained by a plankton net. For this reason it seems advisable to obtain a water sample for centrifugation rather than to rely on net plankton.

When centrifuged samples of plankton collected over the oyster bar are compared with the organisms found in stomachs, even these findings are not always in agreement. For example, on April 25, Cyclotella striata made up 50% of the organisms in a stomach sample, but only 5% of the plankton; and, Cerataulina Bergonii made up only 37% of the food, but constituted 79% of the plankton. Such extreme discrepancies seem to indicate that oysters exercise some selectivity in feeding.

The results of the present investigation to date indicate:

1. There are certain changes in the feeding habits of the oyster, which include an autumn period of feeding and fattening, a winter period of hibernation, and a spring period of resumed activity.

2. The boundary between periods of feeding and hibernation is determined by temperature, which was about 5°C. or 41°F.

3. The nature of the food is determined by the composition of the plankton, which differs markedly in the fall and early spring.

4. Oysters do not ingest large and awkward plankton forms.

5. There is evidence to indicate that, even among the organisms of suitable size and shape, oysters may show "selectivity" in feeding.

This investigation is still in progress and will be continued to obtain a more complete picture of the seasonal and annual variations in feeding habits of the oyster in the Chesapeake Bay.

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OBSERVATIONS ON THE FATTENING OF OYSTERS IN GREAT SOUTH BAY, NEW YORK.

By Joseph B. Glancy
General Seafoods Corp.

I. INTRODUCTORY:

Fatness, in oysters, is a term used by oyster farmers to denote a condition of plumpness of the meats, which at times, fill the shell cavities and attain solidity to such a degree, that the yield on shucking approaches 8 to 10 pints per bushel. Galtsoff (1) has stated the yield in various localities varies from 2.53 to 9.89 pounds per bushel. Studies have been made which indicate that fatness is closely related to the glycogen, accumulation which reaches about 8 per cent in fat oysters as compared with 1 per cent in thin oysters.

The variation in the yield of meats, oftentimes results in a grower in one oyster producing area with well-meated shellfish, having a great advantage over another in a region where oysters are poor. Furthermore, this variation may be emphasized because:

1. Fat oysters are usually associated with increased shell growth which results in the volume of oysters taken from the beds being far greater.

2. The cost of opening is less with fat oysters than with emaciated ones.

3. Plump oysters are sortable into higher proportions of "selects," "extras," and "counts," which command better prices.

It is obvious that an oyster farmer may fail unless his crop fattens. Two remedies are available. First, he can allow the oyster to lay until they improve, assuming his financial and business structure permits; or second, he can transplant to another locality where the water conditions are conducive to fattening. While the oyster is perhaps the most studied scientifically of all the invertebrate animals, there is but little worthwhile knowledge of the water conditions which cause oysters to remain thin, or on the other hand, to grow well and fatten. The purpose of this study is to describe observations made for over ten years in Great South Bay, New York, correlating the conditions of oyster meats with various water factors.

II. METHODS:

Beginning in 1933 and continuing to the present, a record has been maintained of the meats of the oysters in Great South Bay, New York, at West Sayville. These are expressed in pints per bushel of drained meats. Medium sized oysters, in seventy-five pound bushels, were used for the determinations. Every few days, a sample of water, taken off the breakwater of the Bluepoints Company at West Sayville, was examined for:

1. Salinity
2. Temperature
3. pH

4. Diatoms
5. Microscopic swimming forms
6. Small forms

The term "small forms" is used to denote very tiny algae from about one to eight microns, components of the nannoplankton, and most of which encountered in this study, perhaps unclassified scientifically. These have an extremely important significance to the problem of oyster fattening.

The microscopic examination simply consisted of making counts at two magnifications, 60X with a binocular, 120X with a compound microscope, of one cubic centimeter (c.c.) of straight sea water, contained in a Sedgwick-Rafter cell. A c.c. is about twenty drops. The Sedgwick-Rafter cell is a glass slide which holds the one c.c. within an area of 1000 square millimeters and a thickness, or rather depth, of one millimeter. At first, various methods of concentration of the sea water were used, such as the plankton net, the centrifuge, filtration through paper, sand, or Berkefeld filter, but later, it was found that concentration was inconvenient, scarcely necessary, and often undesirable. Of all the concentration means, however, the Berkefeld filter was considered the best. The chief difficulties with concentrating sea water for microscopic examination is that the forms become massed in the detritus, and in case of swimming forms, such as many of the naked dinoflagellates, completely disintegrated. The advantage of the Sedgwick-Rafter cell is that it permits counts to be made on the swimming forms; e.g., dinoflagellates, zoospores, and protozoa by focussing through the one millimeter thickness of sea water, and also estimations of the small form, which stay suspended for several hours within the cell, and which easily pass through filters and centrifuges.

The crustacea, chiefly copepods, were counted directly by naked eye in one hundred c.c. of sample. The tiny nauplii larvae were not included.

The diatoms, including the important filamentous types, were reported as the number of individual cells, which is perhaps not as significant as stating the result in volumetric units to encompass the factor of size of the cells.

Salinity is expressed as parts per thousand, and determined by titration with silver nitrate solution made up with 27.25 grams per liter.

These observations are lacking in that no measurements of turbidity of the water were made, but as the work progressed, it was realized that turbidity in sea water is of great significance in oyster feeding.

No chemical studies were made as, for example, determination of nitrate, phosphate, or potassium content of the water. These should be of value in future studies.

In order to summarize the mass of data, the results have been graphically stated on Keuffel and Esser One Year by Days graph paper No. 358-143L for continuous records of the various factors; e.g., temperature, salinity, pH, crustacea, swimming forms, diatoms, small forms, and meats. To condense the graphs into two charts per year for conveniently correlative purposes, it was necessary to assign for the ordinates, somewhat arbitrary units, obtained by doubling the value of each ascending division. Perhaps some basis exists naturally for this procedure, since most of these organisms, increase by cleavage of one cell to two individual cells. Thus, the graphs, for the microscopic water life are necessarily distorted, and it must be borne in mind that differences on the upper parts of the curves represent far greater numbers than those on the lower.

III. RESULTS:

1. Variations in Meats:

The yield throughout the years varied from about 5 pints to 9.5 pints per bushel. Each year, after spawning, it always dropped to 5 or 5.5 pints. Practically no change occurred in the meats when the water temperatures were below 41°, ordinarily the last week in November to the last week in March in Great South Bay. The time of the year which we are mostly concerned with, in this study, is the period following spawning in the summer, until the winter hibernation, or in other words, the fall feeding season.

Of the eleven consecutive years studied, oysters were fat--meats average and above--8 pints or more, during five years, '34, '35, '36, '37, and '41. In four of the eleven years, '38, '39, '42, and '43, meats were poor, below average-- 5-6 pints. In the two remaining years-- '33, and '40-- the meats were intermediate in fatness, 6 to 7 pints per bushel, which was just about the lower limit for satisfactory marketability. The best meats were encountered in 1941 and the worst in 1943.

2. Small forms:

By far, the dominating factor of the water conditions affecting the growth and fatness of oysters is the presence or absence of the small forms. These are tiny green algae, 1 to 8 microns in size, which at times saturate the water to the extent of 3,000,000 and more cells per c.c. giving the water a yellowish cloudiness and rendering visibility so low that a white disk, 6 inches in diameter, disappears from view when lowered to a depth of only 30 inches. The correlation between the presence of small forms and thinness in oysters is perfect and striking. On the other hand, oysters always grew well, and almost always had fat meats when the small form was absent. Oysters fattened only slowly, however, in '40, when the water showed a marked paucity of all microscopic life, which was indicated by the extreme clearness of the water; objects on the bottom in season being plainly visible in depths of 8 and 9 feet. It is evident that turbidity measurements can be of considerable significance in the problem of oyster fattening.

Usually, these small forms appeared in the water in May or June with temperatures of 60°F. and above, characterized by a typical, spherical type 3 microns in diameter, reaching a peak during the summer, and gradually, almost disappearing in late winter. In 1933, they appeared suddenly in the first week of June, reached a peak of over 3,000,000 per c.c. in July, and began to diminish in August, and practically disappeared during the latter part of September, marked by an immediate increase in fattening of the oysters. This was the only year that it disappeared during the fall feeding season. In '38, '39, '42, and '43, it persisted into the winter months, and oysters, consequently, remained thin during the fall and winter. Unlike most of the other microscopic life which appear, attain peak numbers, and practically disappear, seldom in periods exceeding several months, the small form remains in high numbers, perfectly in suspension, for seasons at a time. Small form growth was always found to be more luxuriant in the fresher water parts of the Bay, adjacent to the mouths of the rivers, and less towards the ocean inlet.

At concentrations below 200,000 per c.c., oysters can grow and fatten fairly well. The effect of high numbers, one million and more per c.c., is to prevent the oyster from feeding. With such concentrations, it was not unusual to find one-half the oysters with empty stomachs and no styles, at water temperatures around 75°F., when feeding should be most active. Observations indicated that the

gills became clogged. The larger oysters seem to be more adversely affected by small form than the smaller, particularly in regard to sulphur sponge, the holes of which penetrate entirely through the shell, the oyster having but little ability to deposit protective shell layers. The meats remain watery and emaciated until it almost seems the oyster must die of starvation. All other lamellibranch shellfish, such as clams and mussels, are also inhibited by small form. In '41, a year when small form was absent, a heavy set of mussels occurred in Great South Bay, which grew very well until the following summer when they began to die. The mortality reached almost 100 per cent before the year ended, and could be reasonably attributed to small form present in 1942.

When the small form occurs in high numbers, light penetration, of course, is considerably reduced, and the oysters dredged are often of black color, as though taken from mud bottom. Heavy worm growths appear, particularly, the "sand coral," Sabellaria, and the calcareous worm, Serpula. Also, the dark hairy bryozoa, Amathia, grows luxuriantly. Evidently, small form presents these animals with a favorable food supply.

2. Diatoms:

Many students of oyster food problems have stressed the importance of diatoms. In these studies, oyster fattening correlated fairly well with growths of filamentous diatoms such as skeletonema and chaetoceras but never when small form was present at the same time as in '33, '38, '42, and '43. The years '34, '35, '36, '37, and '41 were all good fattening years with considerable skeletonema present. For example, during the fall fattening season in '36, skeletonema was constantly present in amounts varying from 300 to 9,000 cells per c.c., and oysters yielded almost 9 pints per bushel.

In this work, diatoms are referred to only by genus, and there was no attempt to delineate species. Diatoms presented two chief types; first, the filamentous, suspended type such as skeletonema, chaetoceras, thalassiosira, and asterionella, to name a few of the most common; and second, the single-celled, bottom type as exemplified by navicula, pleurasigma, and gomphonema. The former correlate with oyster fattening; the latter do not. Skeletonema was the most common diatom. It is literally the grass of the sea. As pointed out by T. C. Nelson (2), it was observed to show in abundance following severe storms. At times, particularly during the winter when diatoms annually in Great South Bay reach their maximum numbers, skeletonema is found at concentrations between 30,000 and 40,000 cells per c.c. In every year, the same general diatom picture occurred--very high numbers during the winter, declining in the spring to almost none in summer, followed by an increase in the fall to the winter maximum, composed chiefly of the filamentous floating types. It is interesting to note that the highest numbers are in the water during hibernation. The bottom diatoms, including filamentous varieties, melosira, and biddulphia, show up particularly during windy weather.

While skeletonema correlates well with oyster fattening, chaetoceras was found to associate with extra good fattening. In the spring of '41, oyster growth was the most vigorous of any of the eleven years, and during that period, we had a maximum chaetoceras. Oysters at that time bore vivid, red streaks in the vicinity of the pericardium thought to be associated with deposition of pigment in muscle scar. This appearance, in such marked degree, is seldom seen in normally growing oysters. The correlation between fast growing, fat oysters and abundant chaetoceras is somewhat surprising, since students of shellfish feeding mechanisms have pointed out reasonably, that the long appended spines of this diatom would im-

pede ingestion as food. It may be that some other factor is involved, such as mechanical aid to the feeding mechanism, just as presence of the small form seem to cripple the oyster's ability to take food.

Chaetoceras, ordinarily shows up to some extent every winter, but when it persists in quantity (300 to 6,000) cells per c.c. as it did in '41 into the summer months, it augurs for good, fall fattening. It is hoped investigators will attempt to check this observation, since it offers a method whereby oyster farmers may be guided in their transplanting operations to insure excellent growth and fatness.

On the other hand, the diatom nitzschia, a single-celled, suspendable form, showing up in quantity (1,000 - 3,000 per c.c.) in the summers of the poor fattening years, correlates as an indicator of unfavorable conditions. It is generally minute in size, and seems associated with small form. Chaetoceras was scarcely ever present with small form. It would appear that water requirements for heavy growth of this diatom are quite the opposite of those for the small form and the diatom nitzschia.

3. Swimming forms:

The microscopic life of sea water is quite complex, and particularly, the swimming elements composed of dinoflagellates, protozoa, zoospores, and larvae. The numbers in Great South Bay water are appreciable, varying from about 50 to around 20,000 per c.c. at times, present during all seasons of the year, but at the maximum during the summer. Occasionally, outbursts of dinoflagellates occur discoloring the water. Some of the naked forms are exceedingly fragile and dissolve in the Sedgwick-Rafter cell, almost before counts can be made.

On the whole, no correlation was found between the swimming forms and fattening. The studies indicate abundant swimming forms may cause thinness. This was supported by some laboratory observations in June '32, at which time the water in the Bay suddenly became discolored, chocolate brown, which was found to be due to the dinoflagellate, prorocentrum, at a concentration of 10,000 per c.c. Oysters in the hatchery troughs, drinking normally, closed and did not feed while this water was allowed to flow through the troughs.

4. Crustacea:

Throughout the year, crustacea, chiefly copepods, may be found in the water from none to 300 per 100 c.c., but in almost every year the greatest numbers are found in the late winter and spring. A fair degree of correlation was observed between abundant crustacea and oyster fattening.

As with the diatom chaetoceras, plentiful crustacea augurs for subsequent oyster fattening. Although T. C. Nelson has pointed out (3) oysters can capture and utilize copepods for food, the significance in our observations is more to associate them with favorable conditions for fattening. In the spring of '41, the year when we had the best growth and meats, the water was discolored in streaks with copepods to such an extent, baymen brought samples of water to the laboratory out of sheer curiosity. On the other hand, during the years of thin oysters, crustacea remained absent in 100 c.c. for long periods.

5. Temperature:

Water temperature is very important, not only in fattening, but all throughout the biology of the oyster. In Great South Bay, because of its shallowness (8 feet average depth), water temperature follows air temperature quite closely. The general curve for temperature is much the same from year to year, with a minimum of 30°F. just before ice formation, to a high of about 83°F. in the summer. Periods are encountered, however, where temperatures run excessively above or below normal, and when sustained, often have important effects on the sea water flora and fauna. For example, high temperatures in early June are productive of good oyster spawning, which if maintained, are most conducive to obtaining an oyster set.

When ice forms, as it does to some extent every winter in Great South Bay, water temperature rises to 33-35°F. on the bottom; and if the ice remains solid over the Bay for several weeks, stratification of salinity takes place, the heavy salt layers settling to the bottom. No distinct correlation was observed between winter ice and subsequent growth and fattening of oysters.

6. Salinity:

A continuous record of salinity was kept, chiefly, to indicate rainfall and the run-off into the Bay. The lowest determination was 16.0 (September '38) and highest, 26.6 (October '43). Rainfall is only slightly reflected in salinity immediately, but the full effect shows within a week or two.

As a general rule, salinity is highest in the late summer and fall in Great South Bay, and lowest in the spring.

The average salinity for each year as compared with the condition of the oyster was as follows:

Year	Salinity	Condition
1933	23.8	Average
1934	22.7	Fat
1935	23.9	Fat
1936	22.7	Fat
1937	23.6	Fat
1938	21.8	Thin
1939	23.1	Thin
1940	23.6	Average
1941	24.7	Very Fat
1942	23.0	Thin
1943	24.0	Very Thin

No high degree of correlation exists between the oyster meats and salinity. Heavy rainfall does not make for fat oysters in Great South Bay. In '38, when abnormal rainfall during the summer, and just previous to the hurricane on September 21, forced the salinity to the lowest point (16.0), observed during the 11 years, oysters remained thin.

7. pH:

The pH determinations were taken colorimetrically, using cresol red, chiefly, as the indicator. Normally, the pH of Great South Bay water is 8.0 to 8.4,

but many determinations were 9.0 and above, while the lowest was 7.4, following the 1938 hurricane. The pH of sea water is affected mainly by sunlight, wind, and temperature. It runs lower in the winter. Cloudiness and wind depress pH. High pH values are fair indicators of excessive plant growth in the water due to photosynthesis.

In these studies, high pH correlates well with thinness in oysters, which is very likely due to the presence of small form, which oftentimes keeps the pH at 8.8 to 9.0 for weeks, and which shows little effect with high winds and cloudiness.

IV. DISCUSSION OF RESULTS:

Perhaps the most important observation made in these studies is to point out not so much what makes oysters fat, as to show what makes them thin. The effect of the small form is almost devastating. One wonders whether the occurrence is confined only to South Bay, or is it widespread and common in occurrence in other oyster producing areas. Due to its small size, it may be that it has been overlooked as a cause of oysters not growing well and fattening, or even undergoing mortalities. Not enough systematic and sustained research has been done on water conditions as related to oyster growth and fatness to venture an opinion on the matter.

The general picture obtained in this work is that oysters are very efficient feeders, and are satisfied with optimum conditions when the water is relatively clear with only scant, organic microscopic life, but not too clear as in '40. Respiration and feeding, closely allied in the oyster, function best under such conditions. The presence of the filamentous diatoms, particularly skeletonema and chaetoceras, even in abundance, does not seem to disturb this picture. By serving directly as food, or perhaps as an aid to the feeding mechanism, they are conducive to good oyster growth and fattening.

These studies seem to show that the microscopic, viable organic content of the water provides the dominating influence. Turbidities, caused by small form, have an extremely adverse effect on the gill feeding shellfish. In a very interesting work on the feeding mechanism of the oyster, T. C. Nelson (4) discusses the effect of turbid water on oysters, concluding that those species with a promyal chamber, should be classified separately into a genus called Gryphaea.

Turbidities may be due to rile by hard winds, resulting in considerable detritus, (microscopic, broken-up, organic matter and fine silt). Appreciable quantities are constantly found in the oyster's gut. The amount of wind action from year to year is quite constant. Therefore, it would seem that detritus is not an important factor in oyster fattening, except that in excessive amounts, it would tend to inhibit the oyster's ability to feed temporarily.

From time to time, unexplained mortalities of shellfish have occurred on oyster beds, such as that in the English oyster (Ostrea Edulis) just after the first world war. This species, without a promyal chamber, may have been quite vulnerable to small form growth, just as the mussels seemed to have been destroyed by it in Great South Bay in '42.

Great South Bay, occasionally produces oyster sets. In the years under observation, this occurred three times,-- '34, '37, and '41. All good oyster fattening years. There are indications that water conditions, satisfactory for adult fattening, are also those necessary for larval survival and setting.

It has often been advocated by oyster farmers, and even scientists engaged in shellfish research, that sea water be enriched by the addition of fertilizers, in order to secure luxuriart growths upon which the oysters would feed and fatten. Based on the above observations, this does not appear to be a promising line of research, unless possibly the microscopic growth obtained, be composed of moderate amounts of certain, filamentous diatoms. In this connection, it is of interest to note that Wells (5) was able to grow various shellfish larvae in surprising concentration, in straight centrifuged sea water.

V. CONCLUSIONS:

1. The history of oyster growth and fattening in Great South Bay shows wide variations from year to year. In the eleven years under observation, oysters were satisfactory for marketing in seven of the years, and so thin in four that an oyster farmer, unless well established, would face failure.

2. Correlation between good oyster fattening and certain water conditions was always observed when: (a) The water was relatively clear, but not too clear. (b) The water contained moderate growths of the filamentous diatoms, particularly skeletonema and chaetoceras.

3. Oysters were always thin when heavy growths of small form, an element of the nannoplankton, was present, even though the diatom picture appeared favorable.

4. Spring and early summer growths of chaetoceras augured for good fall oyster growth and fattening.

5. Likewise, high numbers of copepods during the spring and summer augured for successful, fall fattening.

6. With suitable water conditions, it took about one month, during the fall feeding season, for thin oysters to become fat.

7. The viable, organic content of the water was by far, the determining factor in fatness or thinness of the shellfish, and not the organic detritus.

8. The bottom diatoms were not found to be of importance in fattening.

VI. FUTURE WORK:

It is hoped that these observations in Great South Bay will stimulate somewhat similar work in other oyster producing areas, particularly, to observe on the occurrence of small form. Such studies should be refined, and if possible, supplemented with chemical determinations. From the knowledge gained in the outside water, controlled laboratory experiments could be intelligently and fruitfully carried on. It is felt, such researches would be of great aid to the oyster industry.

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Atlantic City, New Jersey, Meeting, June 1944

SOME OBSERVATIONS ON THE TRANSPLANTATION OF TWO WEEKS OLD SET AND OF OLDER OYSTERS

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Transplantation of "corn on the cob" set has always been a problem. The subsequent yield from planting of such thickly bunched seed has nearly always been disappointing. Excessive crowding results in the death of the majority, while the surviving oysters are usually long and narrow and show poor meats.

On the Cape May shores of Delaware Bay setting of oysters may continue night and day as long as six weeks. Every object in sight is plastered with oyster spat, which in less than a month cover the surface with a solid sheet of oysters. Competition is very keen; our studies show that on the average only one out of each 630 spat attached per square inch of surface is able to reach the age of one year. The other 629 are crowded out and smothered by their fellows, not killed by enemies. The first slide shows the initial stages of this competition with the fastest growing oysters extending their shells over their younger or weaker neighbors. By the first of September baskets of shells put out on the flats are covered with a continuous sheet of young oysters. All oysters within the bag have been destroyed by cutting off of circulation by the oysters at the surface. The only shells which yield a return to the planter are those at the surface of the bag, all those within the bag are wasted. The increasing weight of the bag likewise causes it to sink slowly into the bottom destroying as much as one-quarter of the young oysters on the surface of the bag.

When planted there is much injury to the delicate shells of the rapidly growing young oysters. Many of the spat have grown around the wire; hence, the bag is usually destroyed in emptying and freeing it of the seed. Crabs and other enemies are drawn to the bed by the dead and injured oysters. Once they have eaten the oysters with broken shells, the enemies remain to work on the uninjured oysters. Repeated experiments in shifting these densely set shells in the early fall have failed to yield any return. The young thin-shelled oysters have been destroyed practically one hundred percent. If the set, however, is protected by a cage of wire fine enough to exclude blue crabs and oyster drills, the only mortality which occurs is that resulting from crowding or from accumulated mud. Clusters of fine rapidly growing oysters are obtained.

To avoid the injury resulting from moving "corn on the cob" set, and to secure the maximum yield from the shells, the following experiment was conducted during the summer of 1943. Small baskets made of two foot, one-inch chicken wire such as have been used for oyster drill traps were employed. Into these wire bags were placed only enough shells to form a mass not more than six or seven shells deep from side to side in the center. Thus every shell in the bag was not more than three or four shells away from the surface of the bag at some point. The bags were set in pairs or in sets of three along the edges of the bars on the Cape May Shore on July 1 & 2, 1943. Heavy setting began at once and was still in progress July 16th when the bags were removed and the shells planted within the next four hours on the Parker Grounds in Maurice River Cove. This ground had previously been drill dredged to remove as many borers as possible.

When examined from time to time during the late summer and early fall, it was found that considerable scaling off of the young oysters occurred. This permitted

very rapid growth so that by November 5, less than four months after transplanting, the oysters had reached a length of approximately two inches and width of one inch. The only mortality seen was due to mud on the softer portions of the bed, together with a small death rate from drills. There was no evidence of destruction due to crabs. Examination of the spat at the time of transplanting shows very little crowding; hence, no delicate edges of shell to be broken.

Of great interest is the heavy set on shells even in the center of the bag. Also because of the light weight of the bag and the short time, two weeks, it was left on the shore, there was almost no sinking into the bottom. In other words every shell in the bag bore some spat, most of the shells, a very heavy set. In actual figures this ranged from 108 spat per square inch on the lightly set shells to 450 spat per square inch on the more heavily set shells.

Just what yield per square inch of shell surface can be obtained by such early transplanting is not yet known. It must be very much higher than the one per square inch which survives under our old plan of leaving the shells on the flats until fall. Scaling off begins within a month after the shells have been transplanted and at a time when there may be several dozen young oysters per square inch.

Every biologist will naturally ask; is it wise to save a high percent of a heavy set? Would it not be better to allow competition to kill off the more slowly growing spat, and to plant only the fastest growing survivors. Theoretically, this position is sound and the very rapid growth of coon oysters supports this conclusion. Oysters grown from densely set seed should mature for market at least a year earlier than do oysters from spat set widely apart and in which there is no crowding during growth. Practically however, we find in Maurice River Cove a poorer yield from a dense set than from a light one. On several occasions the natural beds have been closed for a year to allow the seed to thicken up their shells so as to better withstand dredging. In spite of the selection of faster growing oysters which occurs during this extra year on the natural beds, the resulting plantings have been disappointing. In part, this is due to the high percentage of oysters injured in transplanting. In addition, the very thin shells resulting from rapid growth, have made easier attacks by drills. The problem is complicated by the fact that the faster an oyster grows, in general, the thinner its shell and the more vulnerable it is to enemies. Dense set grown in cages clearly demonstrates faster growth, but the practical oyster grower cannot use cages; he must have oyster seed which can survive under the conditions which obtain upon an open oyster bed.

There is an additional advantage in moving dense set before any crowding has commenced. All evidence shows that individual oysters differ as much among themselves as do other animals. If conditions on the ground to which the seed is moved differ markedly from the conditions at the place of attachment, then when the transplanted seed begins to grow and crowd, those oysters best adapted to the new surroundings will be the ones which survive. Under our old system of allowing the crowding and elimination to occur at the place of set, we obtain a crop of seed oysters which are best adapted to meet conditions at that place. They may not be the ones best adapted to the conditions on the new ground to which the spat are transplanted.

During the first two or three days after they set, oyster spat are becoming adjusted to a life of attachment, and are easily killed by low oxygen or other unfavorable conditions. By a week to ten days they are fully adjusted to their new mode of life; hence, there is no danger in moving them after two weeks, provided they are kept moist and are protected from the sun.

Finally, where wire baskets are used to hold the shells, there is much in favor of early transplanting. First, the shells have gained but little in weight from the growing spat. Second, there are no sharp bills to injure those handling the shells. Third, the baskets are overboard for only two weeks. They acquire no growths and if washed at once in fresh water can be used year after year, thus amortizing their cost over a considerable period. The far greater yield per shell planted will soon pay the cost of the basket. Details of the operation can be seen at the exhibit shown at this meeting.

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Atlantic City, New Jersey, Meeting, June 1944

POLLUTION AND THE SHELLFISH INDUSTRY

By Charles G. Hammann
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It has been my good fortune to have attended the last five annual conferences of the organizations represented here today. My usual role has been that of listener but when invited to present a paper on this occasion, the invitation was accepted enthusiastically.

My enthusiasm was diminished, however, when it was revealed that the theme of this portion of the program was to center upon the contributions of bacteriology to the shellfish industry. The presence of several famous and a few infamous bacteriologists, together with my limited knowledge of this profound science, would make my efforts to discuss the subject embarrassing. To add to my discomfort, I learned that one of the gentlemen referred to above was to present a paper on the laboratory aspects of shellfish production. The preliminary program further disclosed that an eminent contemporary was to discourse upon the Manual of Recommended Practice for the Sanitary Control of the Shellfish Industry. Being familiar with both speakers and having read the manual several times, it was reasonable to expect that all phases of shellfish bacteriology would receive thorough attention.

Dr. Galtsoff was generous in the matter of latitude, however, and permitted me to digress. It occurred to me, as I sought a suitable subject, that the pollution problem is one in which most of those present have a common interest. The industry is deeply concerned with the economic effects of pollution, technologists are interested in the scientific phases of the problem, and regulatory people are responsible for preventing human illness caused directly or indirectly by the contamination of waterways. It was decided, therefore, to select pollution in its relation to the shellfish industry as a subject for discussion. To consider this controversial matter exhaustively would require unlimited time but let us review briefly those economic and hygienic aspects of the matter which bear directly upon shellfish production.

The early colonists of America were forced to obtain the essentials of life; food, clothing, and shelter in their most readily available forms. Crudely converted natural resources supplied these needs in most instances. Caves, hide tents, and log cabins served as shelters. Tanned hides, furs, homespun fibers, and handwoven fabrics furnished clothing. Berries, fruits, vegetables, game, and fish provided sustenance. Historic records reveal that shellfish were a principal food resource and that mussels, oysters, and clams contributed substantially to the larders of coastal families. This situation has changed to the extent that not only are shellfish consumed as a staple item of food in localities where they are produced, but are transported long distances to markets where they are considered a delicacy. The consumption of tremendous quantities of all species of shellfish creates a problem of great magnitude in sanitation.

America was destined to become the most highly industrialized nation in history and it was not long before family functions of building cabins, spinning yarn, weaving cloth, hunting game, cultivating gardens, and fishing in streams and seas became highly specialized crafts. Colonists who formerly provided all the needs of their families gradually disappeared. In their places appeared craftsmen who ex-

changed specific abilities in particular trades for comfortable modern homes, custom tailored clothing, and highly refined foods. Later many of these craftsmen were gradually supplanted with the introduction and wide-spread adoption of mass production. Of great significance in this transition was the part played by the rivers, lakes and tidal waters of the nation.

It followed naturally for manufactories to be established on waterways for many reasons; power was needed to operate mechanical equipment, water was required for processing raw materials, and navigable waters provided inexpensive and convenient transportation, to mention a few. Many social and economic disturbances occurred during this period. Several critical problems in sanitation ensued. Among the latter was the serious one of waste disposal. Domestic wastes from redistributed populations and refuse from industrial processes were discharged untreated into nearby waters. Both practices were and continue to be responsible for pollution as the term is used with reference to water sanitation. Each differs somewhat in character.

The term "domestic wastes" is commonly construed to mean sewage in the form of liquid and solid refuse emanating from plumbing fixtures of residential structures. These include human excreta; wash water from bath, laundry, and kitchen,the last frequently containing food particles and sometimes ground garbage; and diverted roof or surface water.

"Industrial wastes" are composed of refuse resulting from manufacturing processes and include effluents from fiber, yarn, cloth, metal, and canning factories as well as animal offal and wash water from slaughterhouses, and a variety of other materials. Sedgwick includes in this category "almost anything capable of carriage by water and small enough to find entrance into sewers."

Unrestrained continuance of these practices resulted in unhealthful and obnoxious conditions which increased proportionately with the expansion of concentrated populations and industrial production. Certain of these conditions were responsible for devastating injury to the shellfish consuming public and to the shellfish industry. Of greatest significance were illness and death attributed to ingestion of shellfish taken from waters contaminated with organisms of enteric diseases. These occurrences caused people to refrain from eating shellfish to a degree that threatened the industry with economic disaster. They also caused the imperative imposition of minimum sanitary standards for shellfish producing waters, which created additional financial and industrial problems. Among these were condemnation of extensive areas theretofore regarded as excellent for oyster conditioning purposes, loss of appreciable quantities of oysters planted in areas too grossly polluted to permit removal for self-cleansing, relocation of shellfish plants or longer hauls necessitated by the development of new beds in more remote locations, and other attendant losses.

These events led progressive planters to combine efforts with other groups in the stimulation of a movement for pollution control that had been started several years earlier following outbreaks of illness through the medium of contaminated drinking water. The objectives of the program were to reduce or eliminate dangerous and undesirable conditions and to prevent their recurrence. Many legislatures created agencies or empowered existing agencies to investigate the matter of pollution and to enforce laws enacted to control the problem. Treatment processes were developed and applied separately or in combination with varying degrees of success. Great advancement was made during the years that followed and it was established that domestic wastes, and to some extent industrial wastes, could be rendered inno-

cuous with modern methods at reasonable costs. Construction of treatment plants followed, offensive conditions were greatly reduced, and prospects for success appeared encouraging. Regulatory officials, consulting sanitary engineers, research workers, and many others were active during this period, and to them belongs credit for the rapid and commendable progress in this phase of environmental sanitation.

Many factors prohibited complete achievement of objectives, however, and undesirable situations continued or recurred usually in modified form. These factors, many of which still exist, included insufficient legislative authority, inadequate funds for research and regulatory activities, lack of public interest, failure of offending communities and industries to accept their responsibilities, and inability to treat certain wastes satisfactorily.

Responsible governmental agencies are constantly striving to overcome these obstacles. Their efforts are frequently supplemented and encouraged by private groups. Activities of this kind can be of inestimable value and should be encouraged. Unfortunately, however, the assistance of shellfishermen, resort operators, wildlife enthusiasts and civic associations have frequently been observed to be so disorganized as to be valueless or even harmful. The first consideration of private groups desiring to participate in pollution abatement programs, therefore, should be the establishment of fundamentally sound organizations.

The next logical step would appear to be the determination of satisfactory objectives. Those defined earlier are felt to be reasonable and commendable and are repeated here in slightly different form; complete elimination of conditions dangerous to public health or offensive to the community. This can be done most effectively in my opinion through the coordinated effort of all related groups utilizing factual information, carefully executed plans, and willingness to compromise. Unfounded allegations, mass agitation, misdirected energy, and selfish attitudes will detract from any program and will usually have harmful effects.

Remaining impediments will resolve into less complex problems and their removal will be found more easily attainable when sound organizational structures and feasible objectives have been provided. Legislatures will be more responsive to recommendations for enactment of statutes and requests for regulatory and research funds. The public, which when aroused becomes a potent influence, will be more sympathetic and helpful. Offending communities and industries will be more receptive to demands that are sensible and economically feasible and will be more likely to accept their responsibilities. Enlightenment created by these procedures will reduce pressure exerted by private interests which frequently causes political tolerance. The discovery of satisfactory treatment processes for wastes not amenable to known methods depends entirely upon applied research, and progress is continually being made in that direction.

In closing, I reiterate that the practice of discharging untreated or partially treated domestic and industrial sewage into streams, lakes, and tidal waters continues to be responsible for illness, discomfort, and economic loss. This period of post war planning seems to be an excellent time to take inventory, organize, decide upon a course of action, and engage energetically in a coordinated program to attain the proper objectives. It remains to be seen whether or not the shellfish industry, the existence of which depends upon the execution of adequate pollution control measures, will respond to the limits of its ability and resources.

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THE BACTERIOLOGY LABORATORY - A TOOL OF THE PROGRESSIVE OYSTERMAN

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In the course of my experience with the oyster over the past 5 years, I have become impressed with the psychological reaction which accompanies the mere mention of "bacteriology" or "laboratory tests" in regard to shellfish. Awe, fear and defense reactions appear simultaneously and with suddenness.

The reasons for these emotional displays are perfectly understandable. They have their origins in simple but real experiences. The dramatic effect of infectious disease, the regulation of the industry by public health officials and the continual awareness of the industry of its responsibilities in maintaining a high degree of wholesomeness and safety in its product, lays a burden upon the oysterman which is heavy, hence his allergy to any mention of this phase of his work. Furthermore, it is difficult for him to understand some of the technical aspects of bacteriological control and he becomes wary of the laboratory workers.

It is my purpose today to attempt to dispel this wariness by briefly indicating how you, as oystermen, can employ the bacteriological laboratory as a tool for your own advantage. I want to point out how bacteriologists generally are equipped to assist you in the development of your industry and to indicate how the facilities now at your disposal can be used to your advantage.

I shall try to do this by discussing 2 fields of investigation which are of interest to the oyster industry. The first, and the one with which you have had the greatest concern, is sanitation. The second is, in a sense, a new field because it has been almost completely neglected. This is the role of bacteria in the nutrition of the oyster and their influence on the quality of the oyster as food. There undoubtedly are other bacteriological problems which should be looked into. Technological advances will lead to the necessity of making new types of investigations but it is impossible to review all of these possibilities at this time.

Any outbreak of infectious disease due to shellfish is doubly embarrassing: to the shellfisheries because it leads to a temporary loss of public confidence in the oyster as safe food, and to the public health bacteriologist because he knows that such incidents are preventable by the adoption of proper sanitation practices. The current sanitary regulation of the shellfish industry is aimed at the maintenance of consumer confidence in shellfish as food. The necessary control measures upon which the industry frequently frowns are directed not at the producer but primarily at the development of a food industry upon which the public can rely with safety. Since the shellfish industry differs in many respects from other food industries, its problems are unique and require special treatment, but the work should be done with the consumer in mind, thus enhancing the industry through increased oyster consumption.

While it is true that the development of consumer confidence is an initial motive, this goal frequently has been obscured. Each oyster-producing state has separate control measures for the industry and this leads to confusion which is exaggerated by the unfamiliarity of certain of the enforcement officials with the oyster

industry. This occasionally results in bureaucratic control which creates a chasm between the industry and scientific advancement. Thus it is necessary to restrict sanitation control to practical essentials, keeping an open mind for the consideration of future developments.

In order to accomplish this, a control program, coordinated with regard to the best consumer and production interests must be developed. To accomplish this, the shellfish industry should be assisted in understanding and adequately complying with the sanitation regulations. An effort should be made to eliminate as far as possible the inconsistencies which may arise from time to time in the regulatory codes and an agency should be set up to act as a liaison between the industry and enforcement groups.

But the public health program cannot stop here. If the best interests of the shellfisheries are to be served, the oysterman must initiate some of the measures, since he alone knows the industry intimately. To do this, he must work in close cooperation with the bacteriologist, bringing his ideas and problems to the laboratory. Here new control measures may be developed which are aimed at the improvement of the product. The stimulating impulse will be the development of an attractive food. It is this type of research which will pay the greatest dividends.

It is unfortunate that the emphasis on disease-producing bacteria should have led the average person to the belief that all bacteria are harmful. As a matter of fact, the great majority of them are harmless and some even valuable. By exploiting these forms, we can greatly enrich our lives. The activities of certain of these minute organisms give us cheese, beer, solvents, increased soil fertility and a myriad of other things. To date we have done very little with such organisms to enhance the shellfisheries.

That bacteria may serve as sources of food for mollusks has been known for some time. The nourishment may be obtained either by ingesting the bacteria directly or the oyster may feed upon planktonic forms which in turn feed upon bacteria. The question of which bacterial types are best suited for either the direct or indirect nutrition of the oyster has never been given serious consideration.

Recent studies in the U. S. Department of Agriculture and elsewhere have shown that bacteria may be very efficient vitamin producers. Can the vitamin content of the oyster be increased by having it feed on these forms? Does an increased vitamin intake serve to improve the physiological condition of the oyster so that it gets "fatter" or more palatable? Does the maintenance of reproduction depend upon the types of bacteria available to the oyster?

Here is an opportunity for the shellfish producer to work hand in hand with the bacteriologist in producing a better food through micro-biological control. It is a chance to use this tool, bacteriology, in developing a superior product. Whether or not this work is done depends chiefly upon the oyster industry. The facilities and trained personnel are available but the work cannot be done without cooperation.

Little is known concerning the bacteriology of shellfish subjected to various technological processes. How can the bacterial content of oysters be controlled under present methods of shipping, handling and storage? What should be known about frozen oysters? Will dehydration maintain the quality of oysters shipped to distant places? At present we have either no answer to these questions or our answers are inadequate. Again the shellfish industry can use the laboratory to assist in obtaining the proper answers.

By citing problems where the need for further information is obvious, I have attempted to show how the laboratory can be of service to the shellfish industry. But have I sold you the idea to a degree where you, as oystermen, will demand and depend upon the services of the bacteriologist and his laboratory? I am not so stupid as to believe that I have. I am certain that I have not convinced those of you who have never seen a bacterium that these organisms really exist. I have not taken you into the laboratory and demonstrated their multifold activities. Bacteriologists have seen your plant, your methods and know your operations but have not returned your hospitality. My colleagues and I come to your meetings annually, speak a tongue which is foreign to you and talk about things with which you are not familiar. At best we have been dull guests.

Therefore, I suggest that you drop in on us sometime. Stay a few days and let us show you around. I believe that you'd enjoy the visit and get a much clearer idea of what we do and why we do it.

You would find, for example, that a laboratory is no mystic temple; it is literally a work shop - a place of manual labor. The age of the alchemist is passed; our object is to learn facts, not make magic. It would soon become apparent that you need not be ashamed to ask questions because we, the laboratory workers, spend our lives asking them. You would see that we possess three virtues as far as your industry is concerned,- we can prevent some of your difficulties; we can solve some of your current problems; we can guide you upon new roads of endeavor. If we can convince you of this, we shall soon be working in complete unison.

In all sincerity, I ask you to accept this invitation literally. Let us arrange to show you our house so that we may work together to make the shellfisheries a sound, progressive food industry.

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1947, 1948